



# Tracking Consciousness in noncommunicating states

New Scientist Instant Expert: Consciousness  
March 24 2018, London UK

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Human Brain Project



# Patients cannot express themselves



Hable con ella 2002, Pedro Almodóvar





# The mechanical ventilator (1950s)

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Bjørn Ibsen  
(Copenhagen)

**The resuscitation greats**  
Resuscitation. 2003

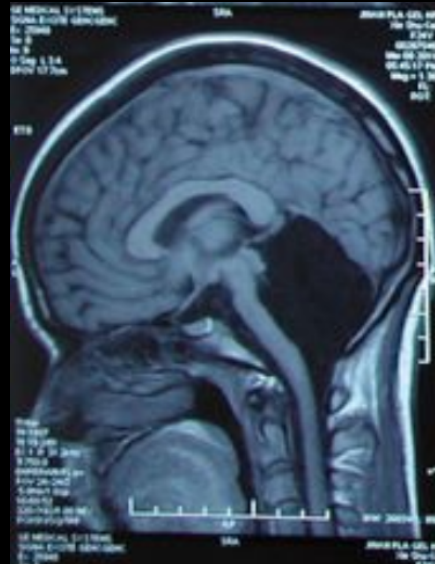


# We need a brain

Typical brain



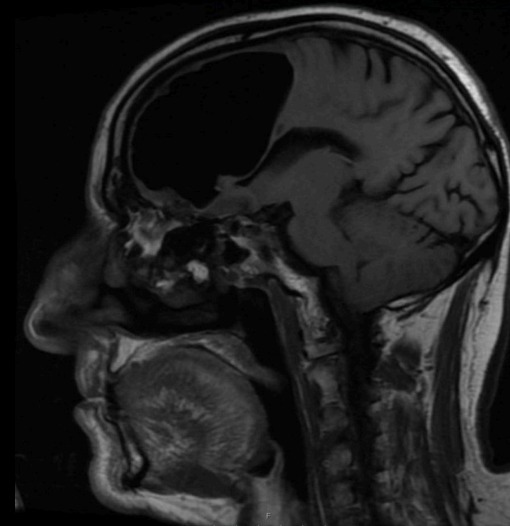
Primary cerebellar agenesis



24y female

Yu et al, Brain. 2014

Frontal air-filled cavity

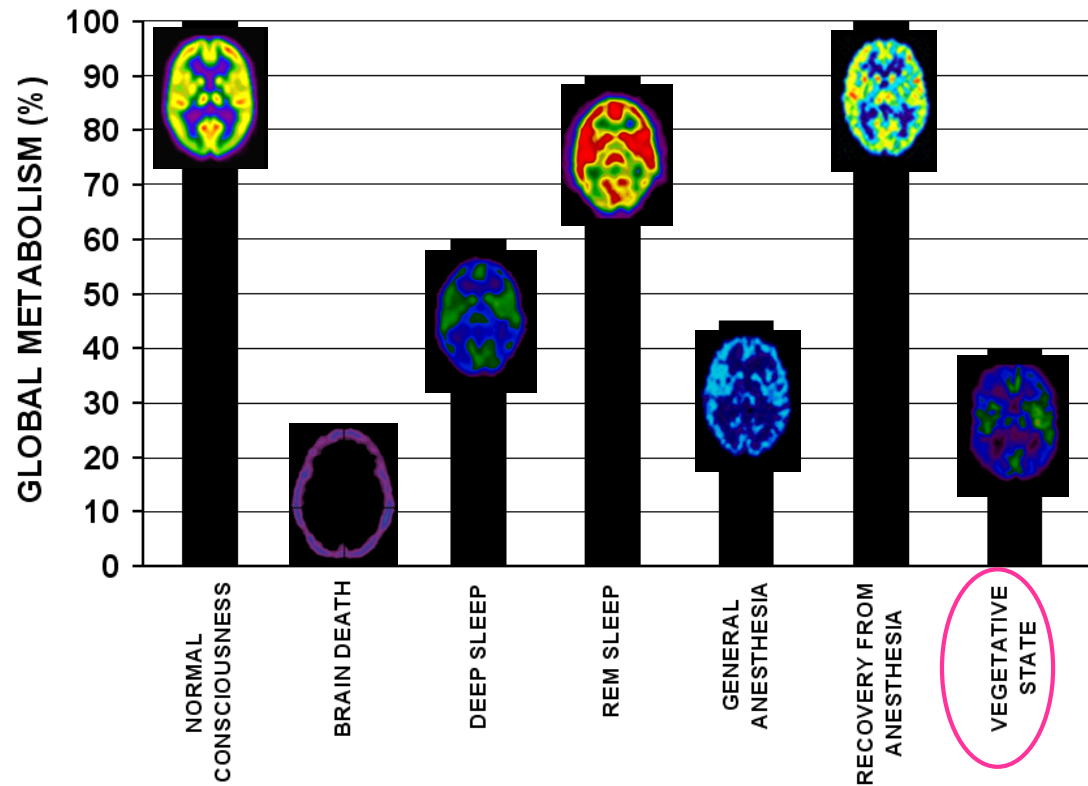


84y male

Brown & Vahidassr, BMJ Case Reports 2018



# We need a functional brain

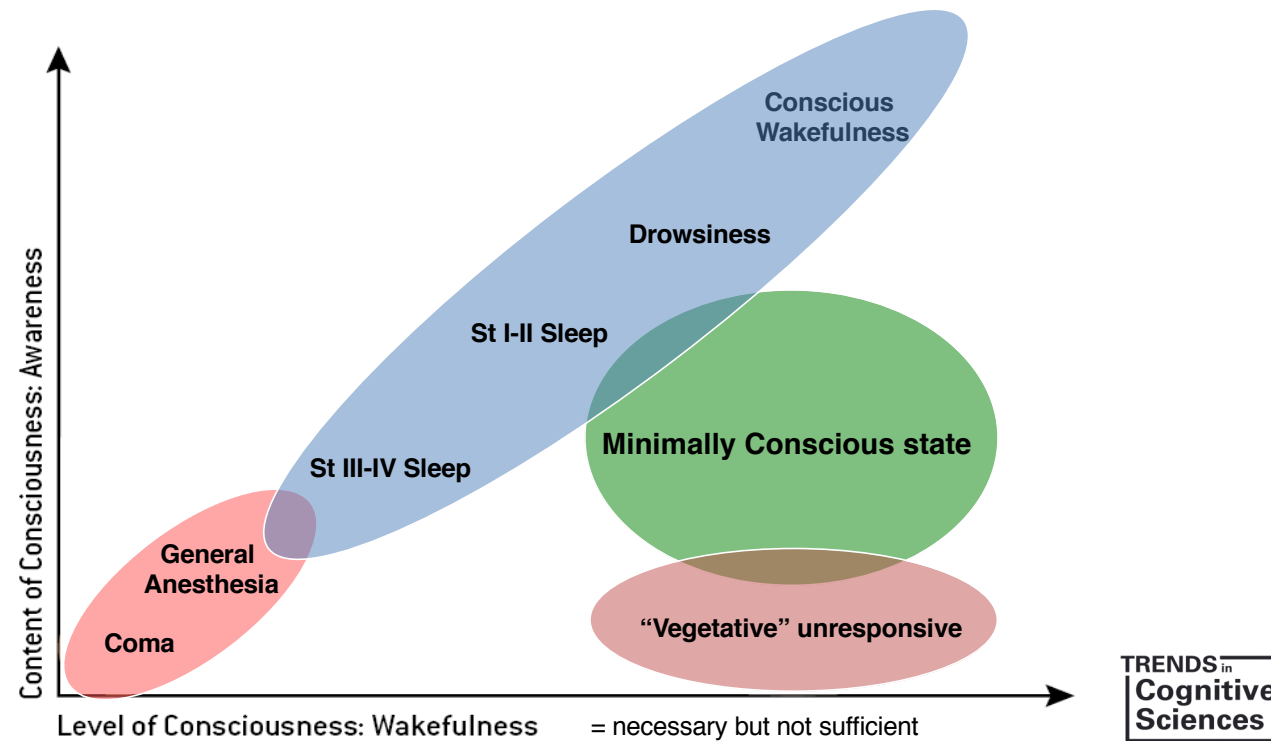


Laureys et al., Lancet Neurology, 2004  
(sleep data from Pierre Maquet; anesthesia data from Mike Alkire)





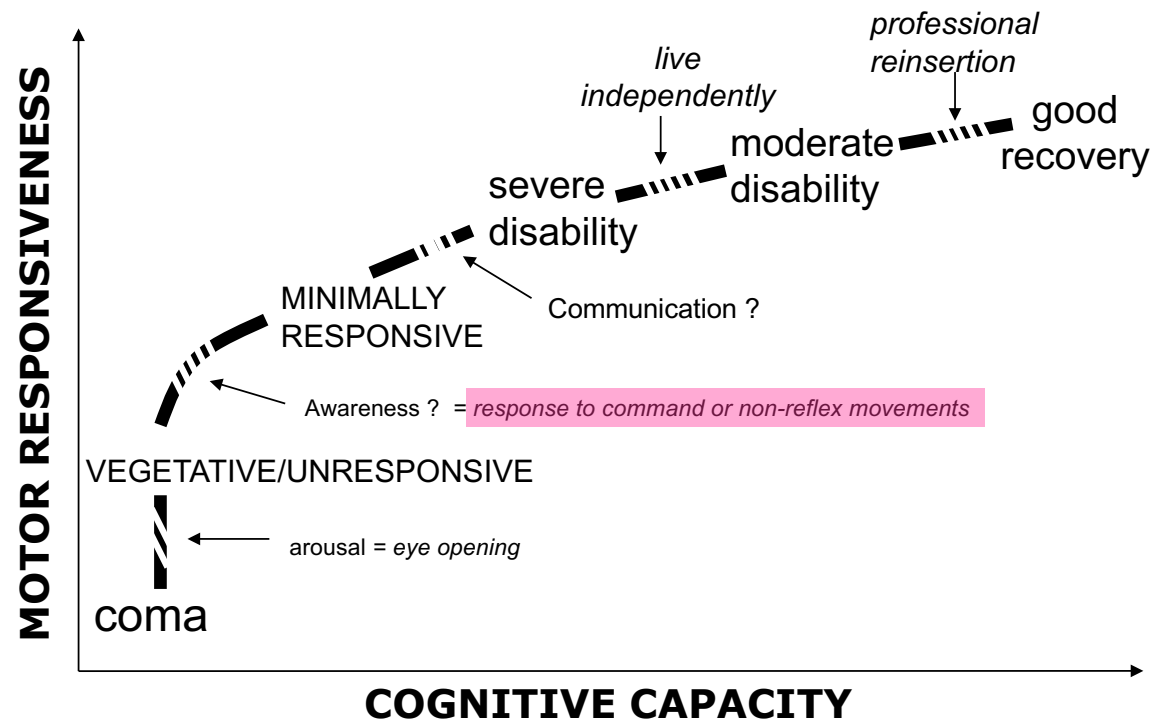
# Disorders of Consciousness



Demertzi, Boly, Laureys. *Encyclopedia of Consciousness* 2009  
Laureys. *Trends Cogn Sci* 2005; Laureys et al, *Nat Clin Med* 2008



# Behavioural signs of Consciousness





## Response to command: behaviour

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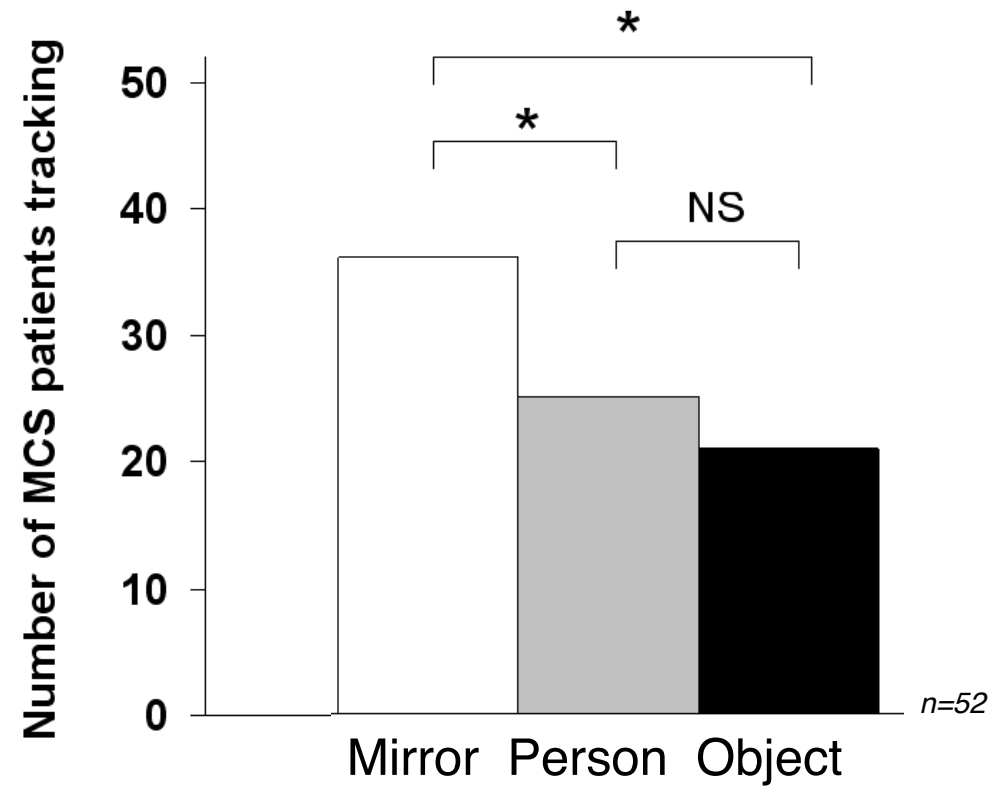


Terry Schiavo °1963,  
vegetative 1990, † 2005 USA





## Non-reflex movements: eye tracking



# But: Is behaviour the gold standard?

## Standardized assessment

n=103 post-comatose patients

45 Clinical diagnosis of VS

18 Coma Recovery Scale MCS

 40% misdiagnosed

Schnakers et al, *Ann Neurol* 2006; *BMC Neurol* 2009

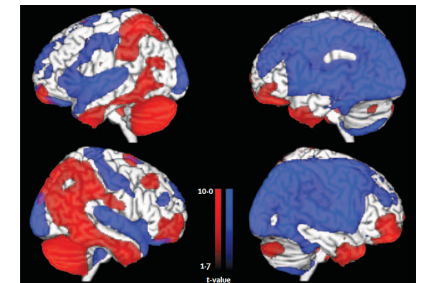
## PET Neuroimaging

Coma Recovery Scale-Revised results			
	UWS	MCS	Total
Clinical consensus diagnosis			
<sup>18</sup> F-FDG PET			
VS/UWS	24 (21%)	5 (4%)	29 (26%)
MCS	12 (11%)	71 (63%)	83 (74%)
Total	36 (32%)	76 (68%)	112 (100%)

UWS=unresponsive wakefulness syndrome. MCS=minimally conscious state.

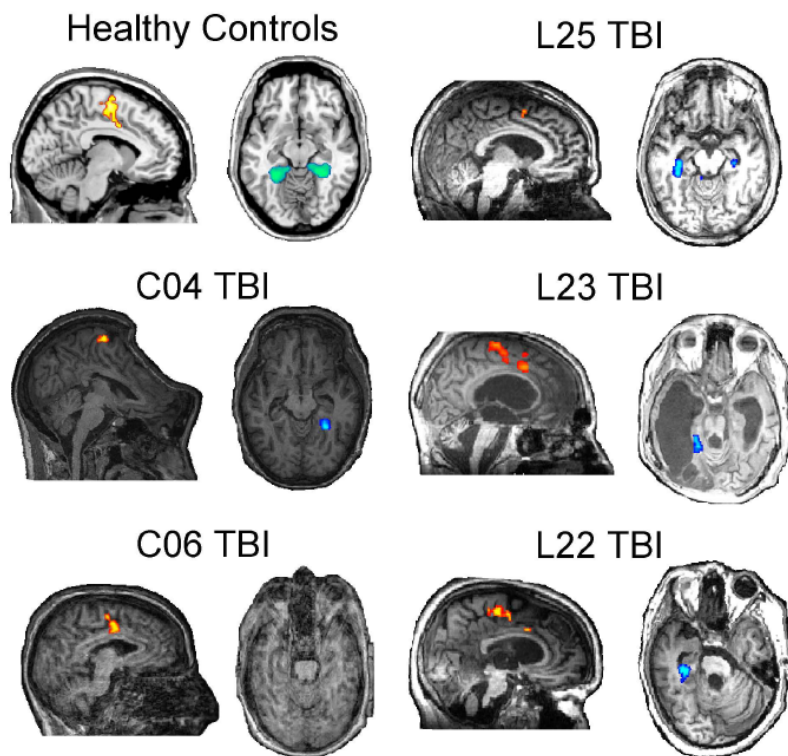
Table 2: Diagnostic results by modality

Stender & Gosseries et al, *Lancet* 2014



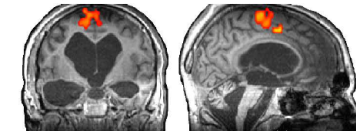


# Response to command: brain activity

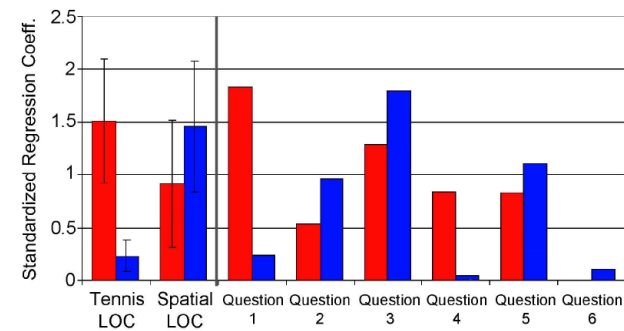
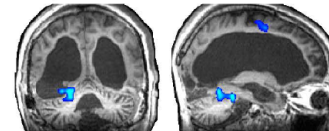


Imagine **Tennis** to answer 'YES'  
Imagine **Navigating** to answer 'NO'

Is your father's name Alexander ?



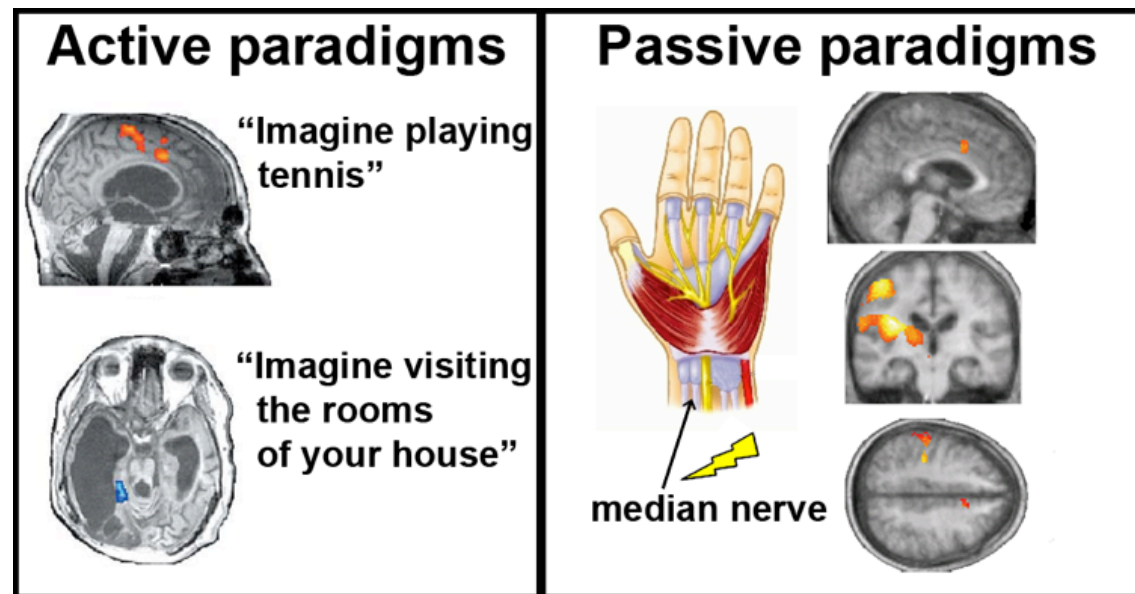
Is your father's name Thomas ?







## *But: what when not possible?*



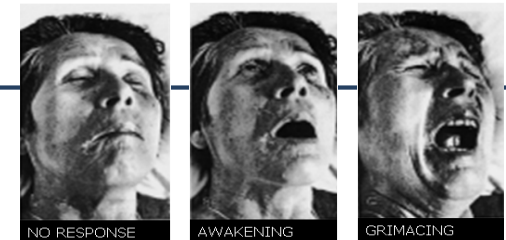
Heine, Di Perri, Soddu, Laureys, Demertzi  
In: *Clinical Neurophysiology in Disorders of Consciousness*  
Springer-Verlag 2015

Demertzi & Laureys, In: *I know what you are thinking: brain  
imaging and mental privacy*  
Oxford University Press 2012

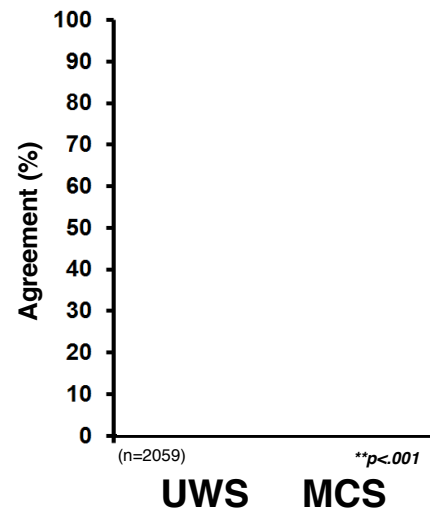


# What is awareness?

Nociception, pain, suffering?

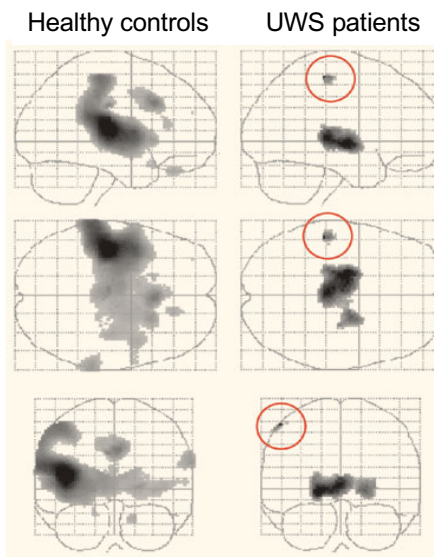


Do you think patients in a ...  
can feel pain?



Demertzi et al, *Prog Brain Res* 2009  
Demertzi & Racine et al, *Neuroethics* 2012

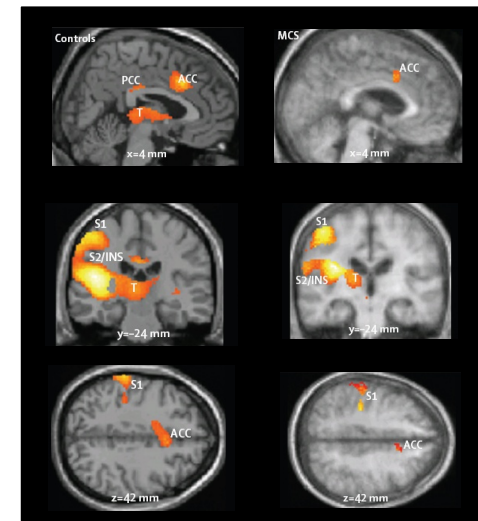
Unresponsive wakefulness syndrome



Laureys et al., *Neuroimage* 2002

Minimally conscious state

Healthy controls MCS patients



Boly et al, *Lancet Neurol* 2008



A black and white portrait of a man with a full, dark beard and mustache. He is wearing a dark suit jacket over a white shirt and a dark bow tie. The man has a serious expression and is looking slightly to the right of the camera. The background is dark and out of focus.

# Saul Steinberg



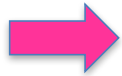




# Some numbers

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- The brain is ~2% of the weight of the body
- 80% of energy consumption supports neuronal signaling
- Performance-evoked changes in energy consumption <5%



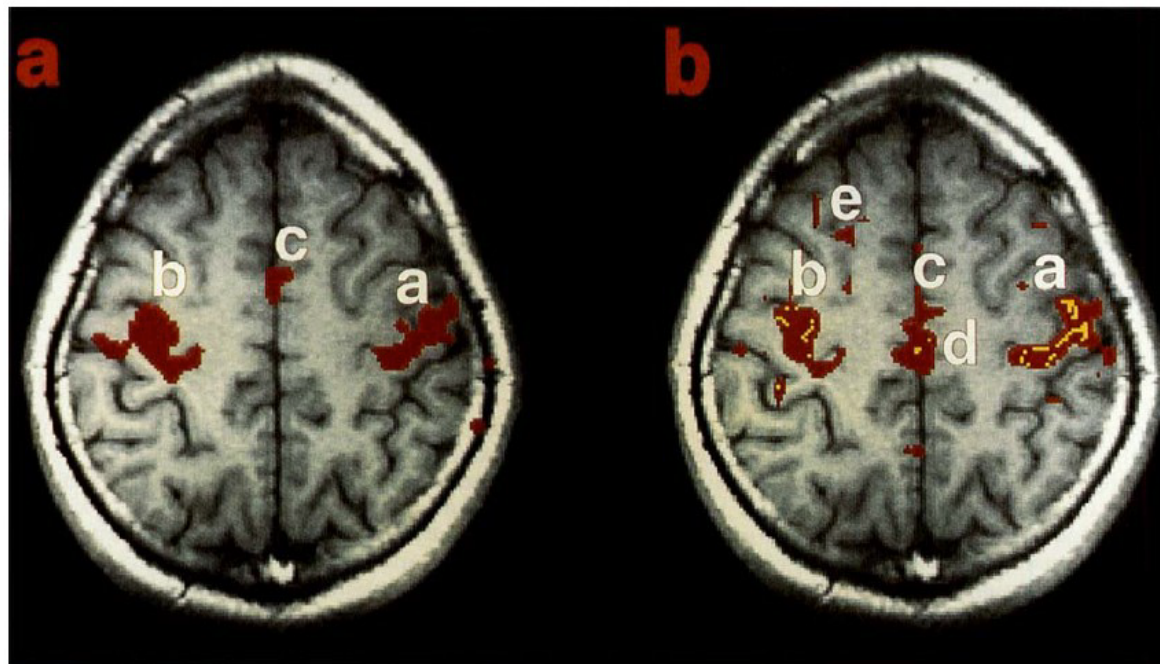
*While conscious awareness is energetically inexpensive,  
it depends on a very complex, dynamically  
organized, non-conscious state of the brain that is  
achieved at great expense*

# The brain self-organizes

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**Task**

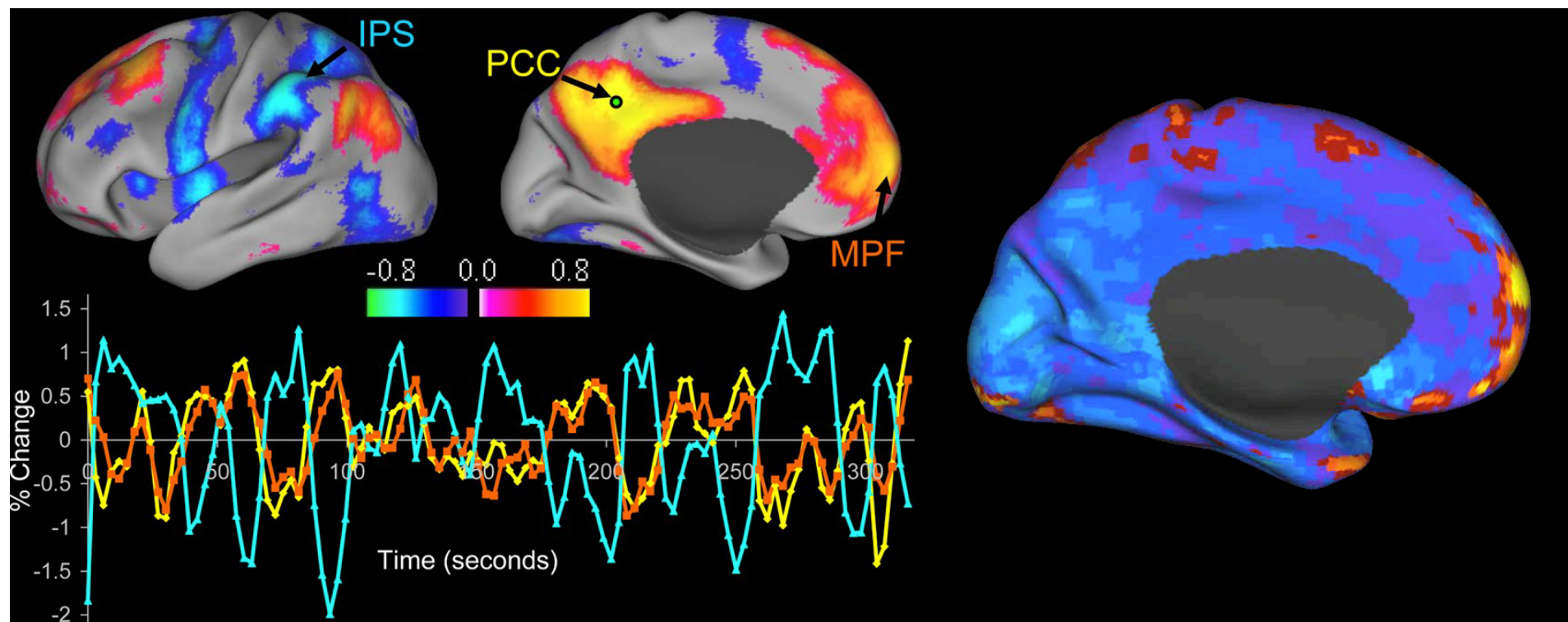
**Rest**



Biswal et al., *Magn Reson Med* 1995



## Default mode function

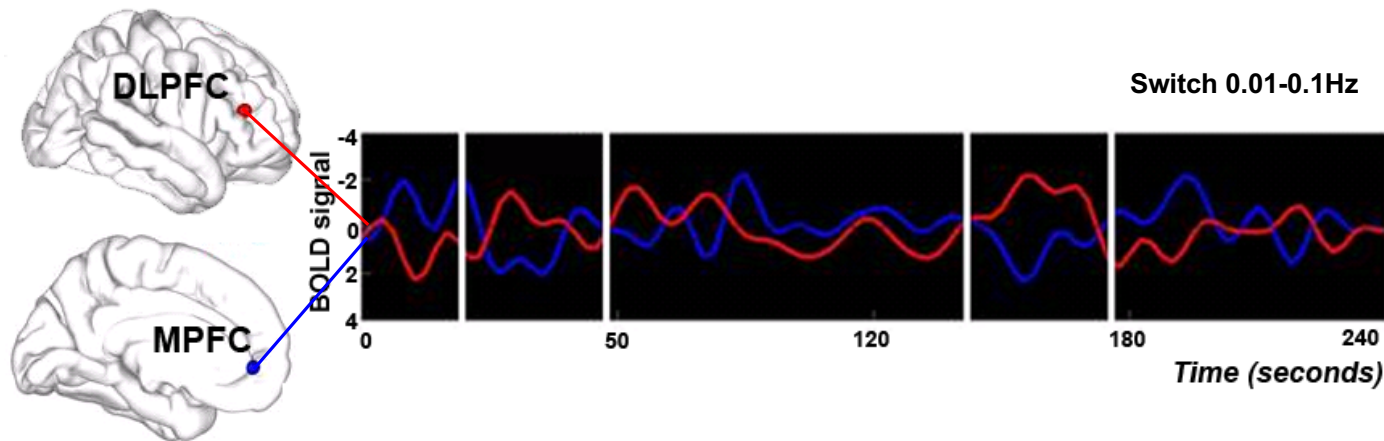


Fox et al, *Proc N Acad Sci* 2005



# Default mode function: cognition?

External awareness  
or anticorrelated network



Internal awareness  
or Default mode network

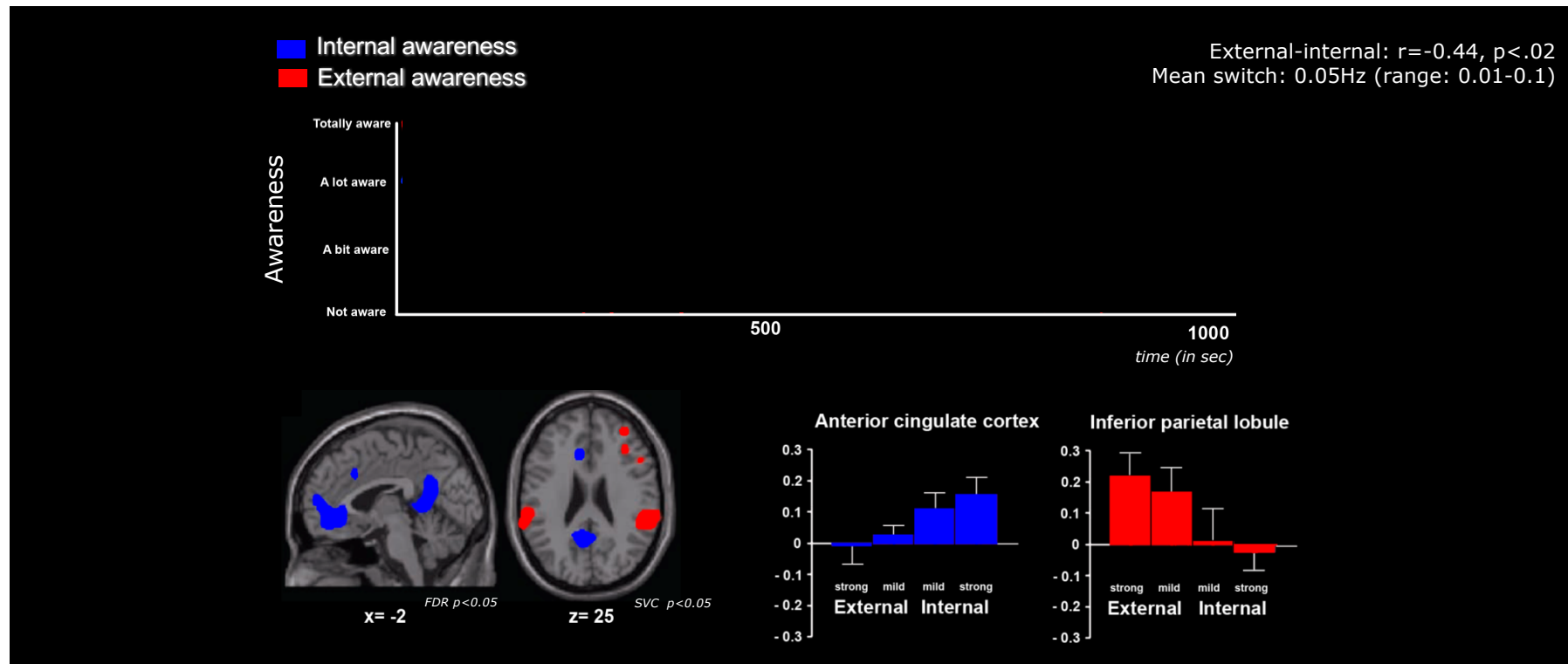
Demertzi & Whitfield-Gabrieli. in: *Neurology of Consciousness* 2<sup>nd</sup> ed. 2015

Demertzi et al, *Front Hum Neurosci* 2013

Demertzi, Soddu, Laureys. *Curr Opin Neurobiology* 2013



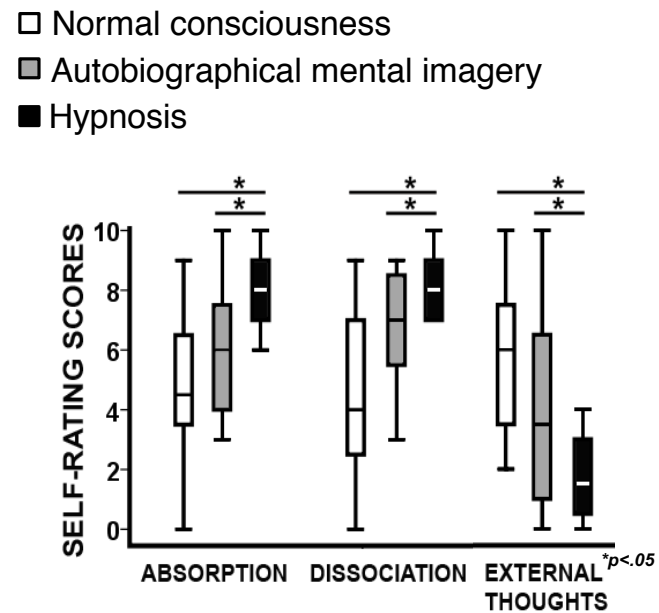
# Cognitive-behavioral relevance



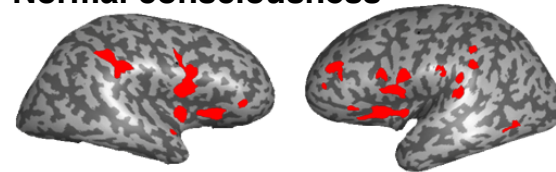
Vanhaudenhuyse\*, Demertzi\* et al, *J Cogn Neurosci* 2011



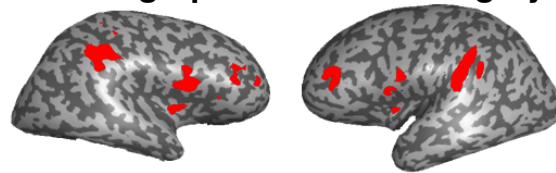
# Effect of awareness



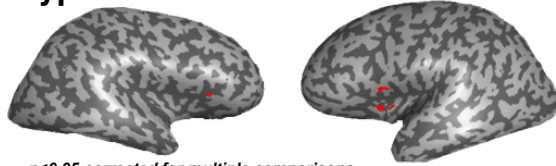
## Normal consciousness



## Autobiographical mental imagery



## Hypnosis



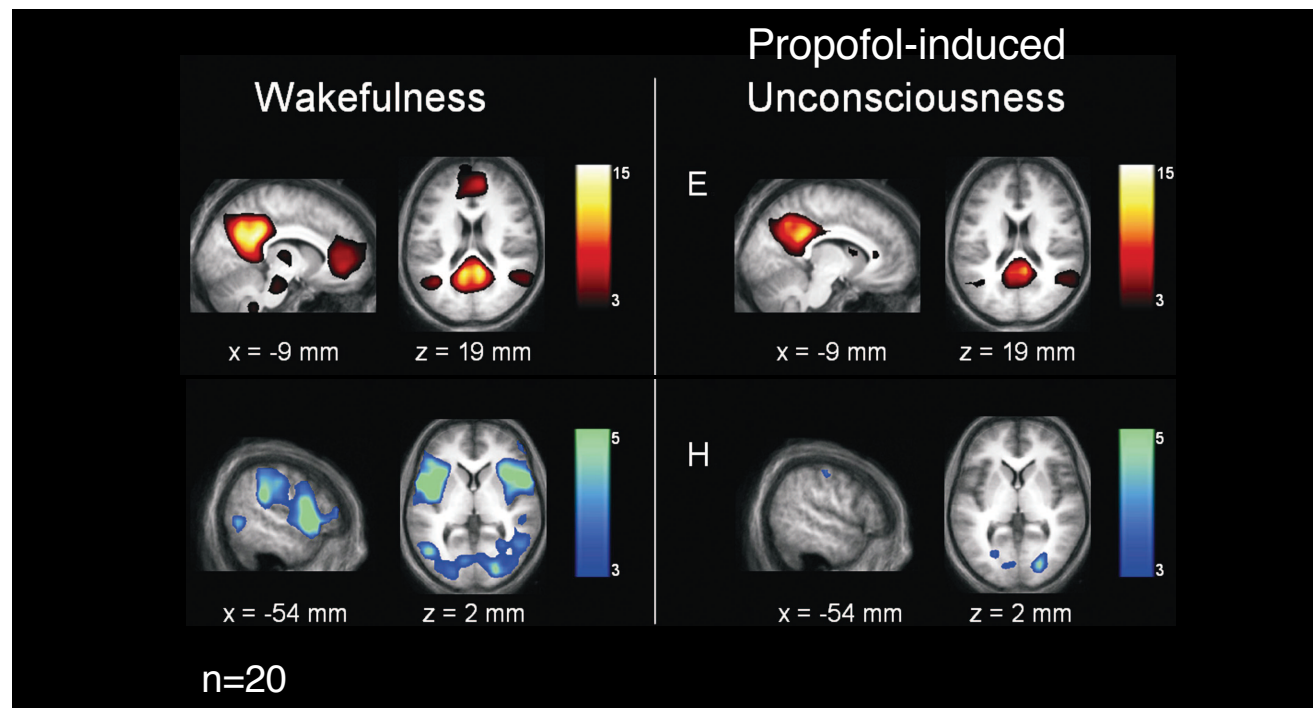
*p<0.05 corrected for multiple comparisons*

Demertzi, Soddu, Faymonville et al, *Prog Brain Res* 2011

Demertzi, Vanhaudenhuyse, Noirhomme, Faymonville, Laureys, *J Physiol Paris* 2015



# Effect of arousal



Boveroux et al, *Anesthesiology* 2010

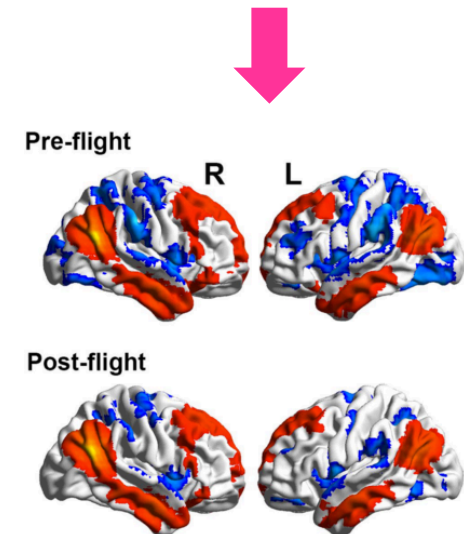
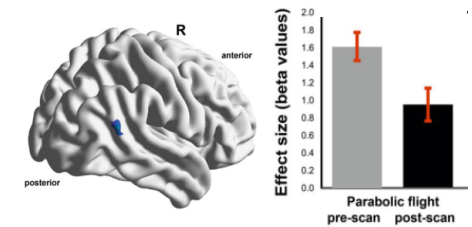
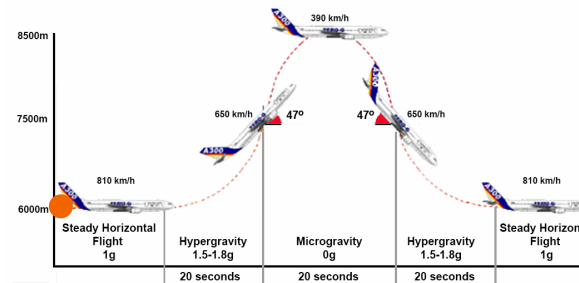




# Effect of environment

SCIENTIFIC REPORTS

## Parabolic flight trajectory

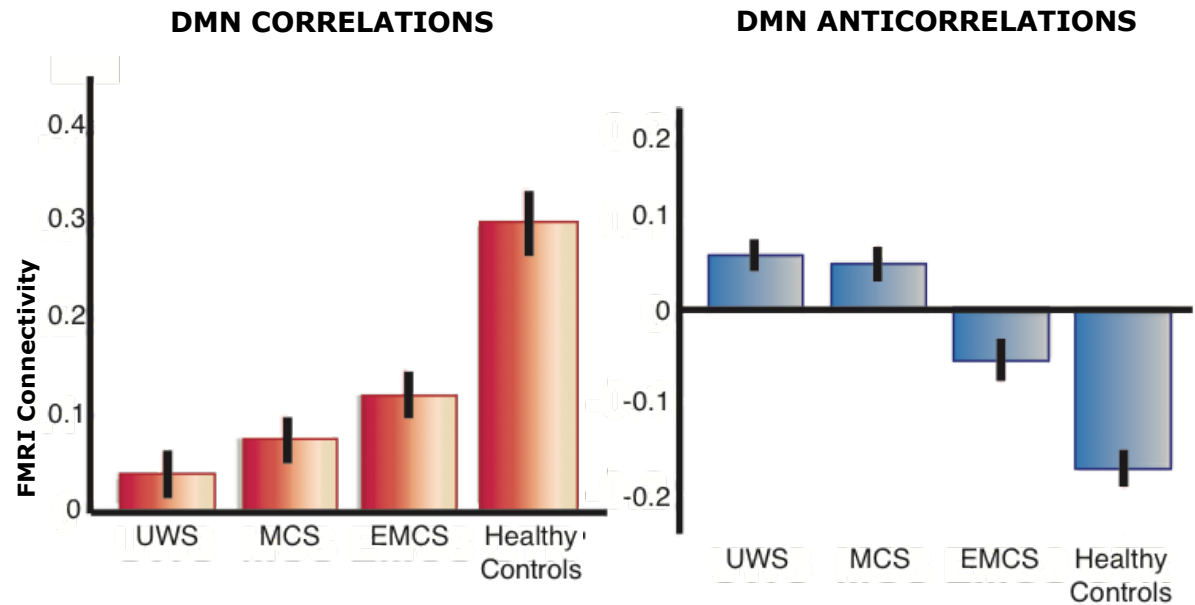
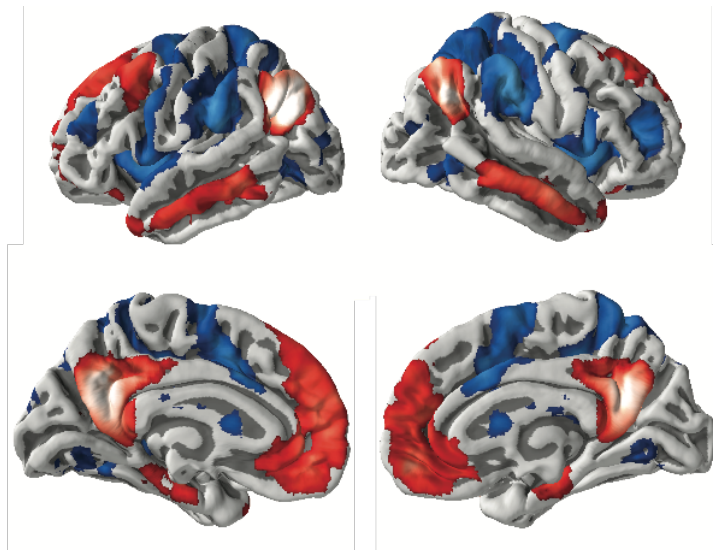


Angelique Van Ombergen<sup>1</sup>, Floris L. Wuyts<sup>1</sup>, Ben Jeurissen<sup>2</sup>, Jan Sijbers<sup>2</sup>, Floris Vanhevel<sup>3</sup>, Steven Jillings<sup>1</sup>, Paul M. Parizel<sup>3</sup>, Stefan Sunaert<sup>4</sup>, Paul H. Van de Heyning<sup>1</sup>, Vincent Dousset<sup>5</sup>, Steven Laureys<sup>6</sup> & Athena Demertzi<sup>6,7</sup>



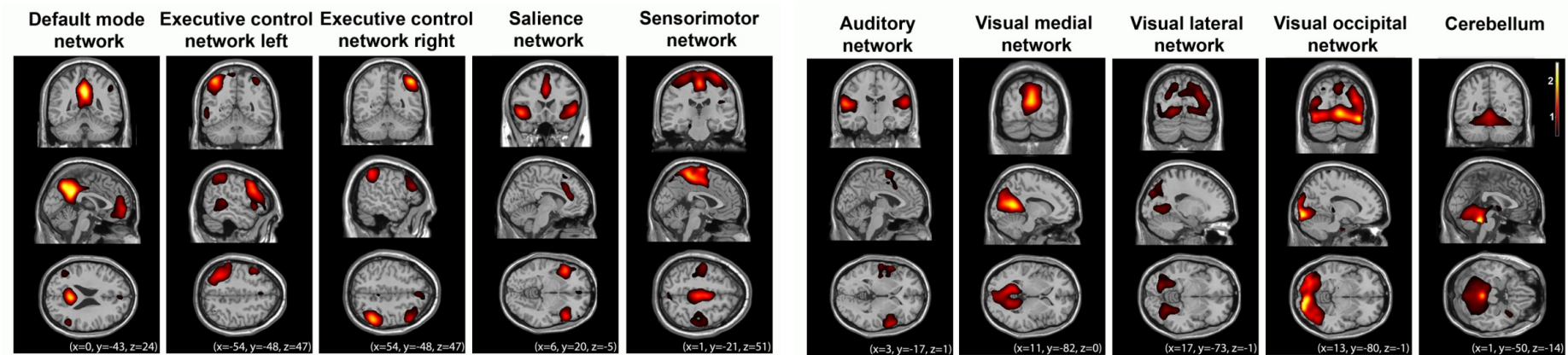


# Effect of pathology





# Brain networks

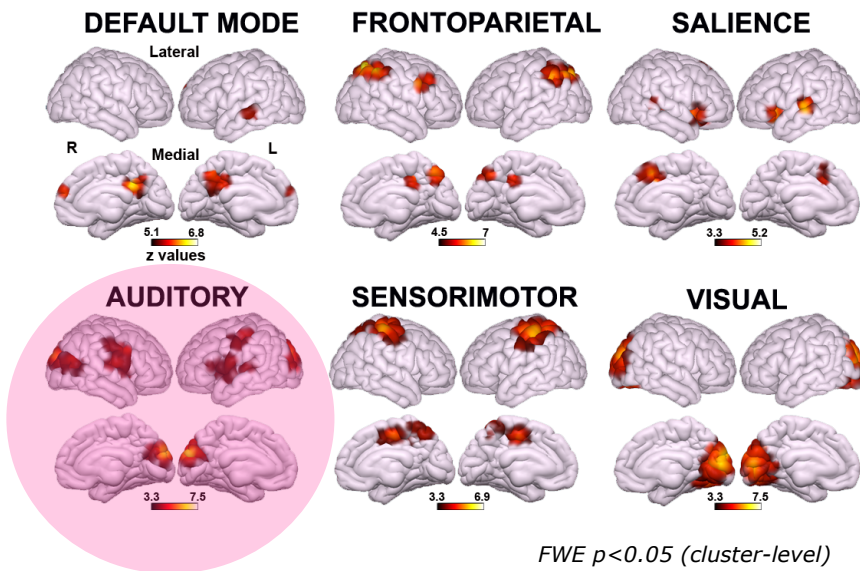


Heine, ... & Demertzi, *Front Psychol* 2012



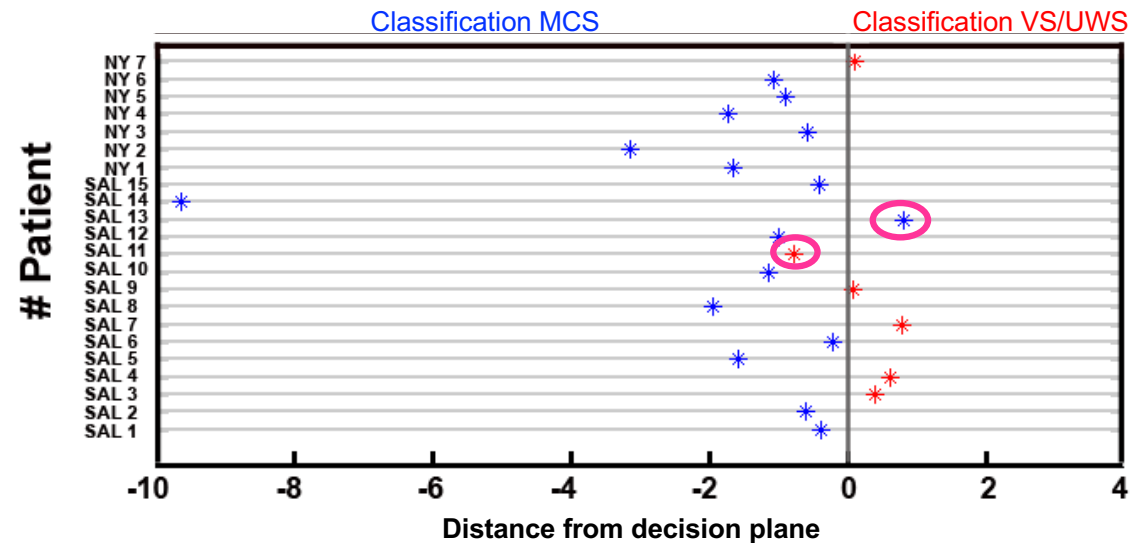
# Which network discriminates best?

## MCS > VS/UWS



## Single-patient classification

Training set: 45 DOC (26 MCS, 19 VS/UWS)  
 Test set: 16 MCS, 6 VS/UWS 2 different centers

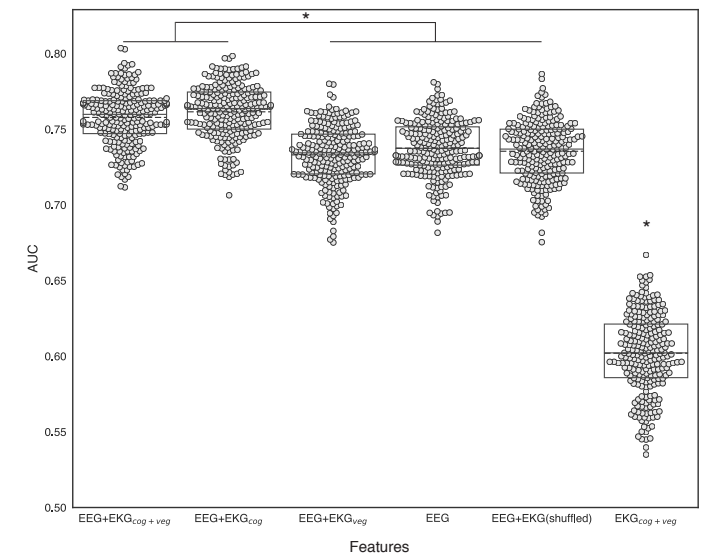
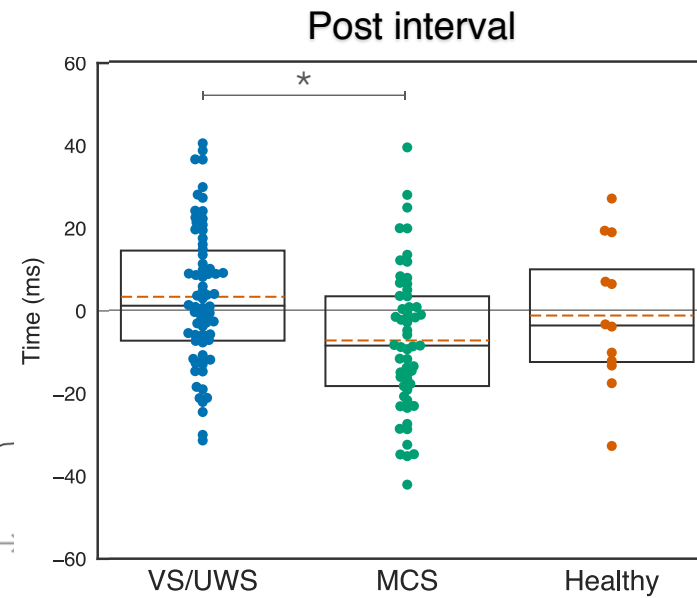
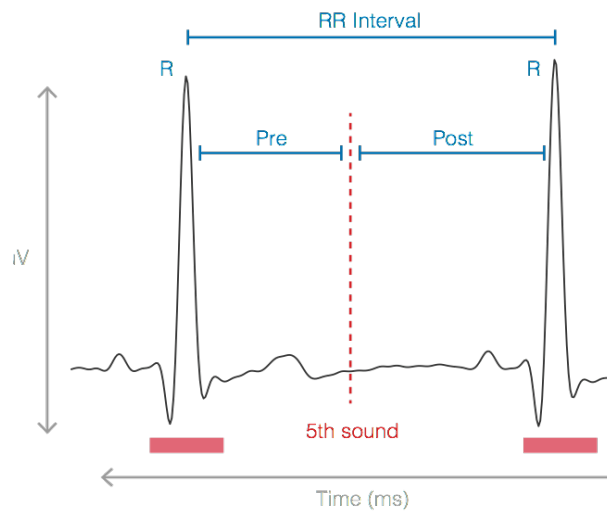


Demertzi & Antonopoulos et al, *Brain* 2015  
 Demertzi et al, *Neurosci Consciousness* 2017



# Listen to the heart

## Auditory oddball paradigm



Raimondo, Rohaut, Demertzi et al, *Annals Neurol* 2017

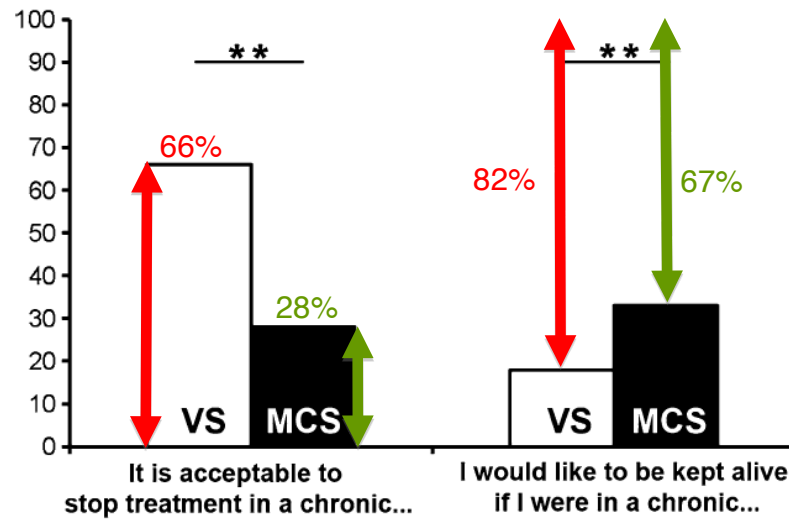


Why does it matter?



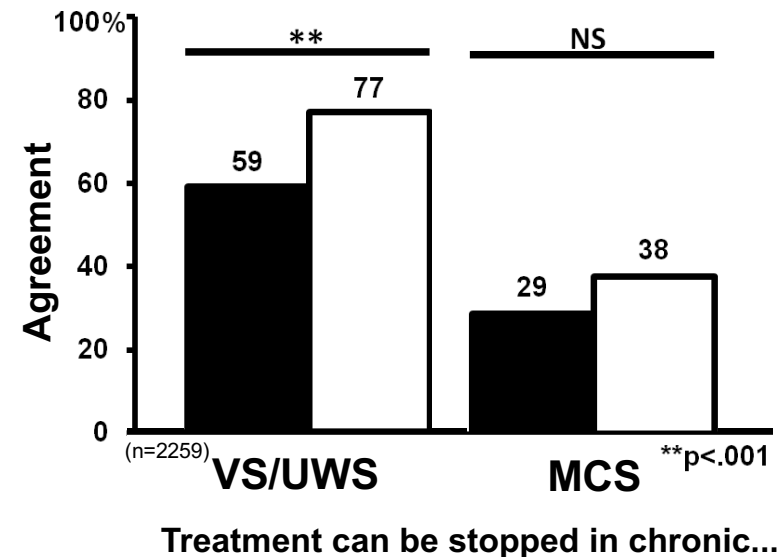
# Consciousness has a moral significance

2,475 medical professionals



Demertzi et al, *J Neurol* 2011

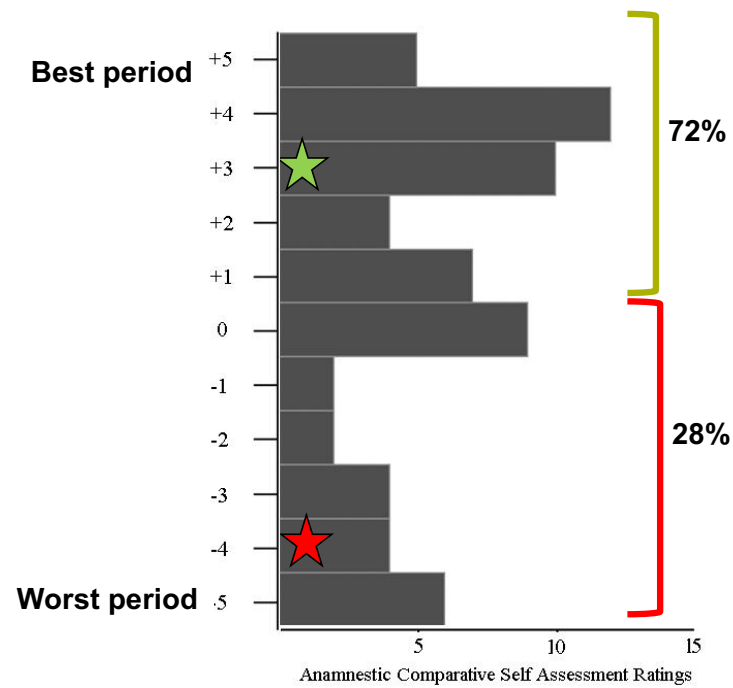
■ Feel pain  
□ Do not feel pain



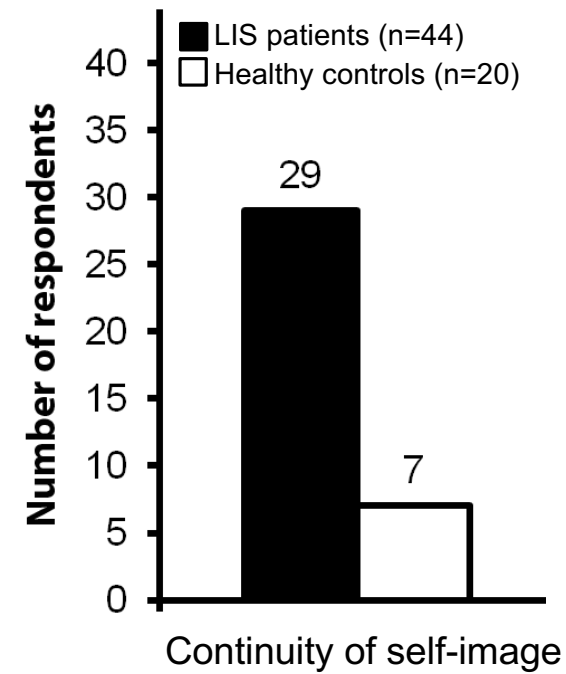
Demertzi & Racine et al, *Neuroethics* 2012



# Quality of life



Bruno et al, *Br Med J Open* 2011



Nizzi & Demertzi et al, *Conscious & Cogn* 2012



What remains unsolved?



# Patients cannot express *themselves*

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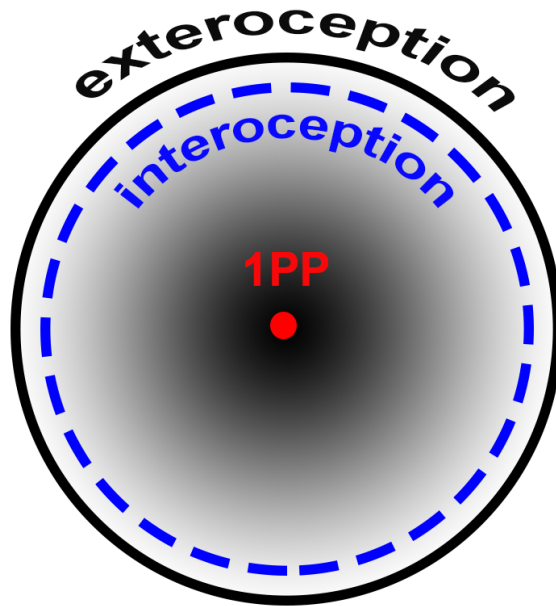
Hable con ella 2002, Pedro Almodóvar





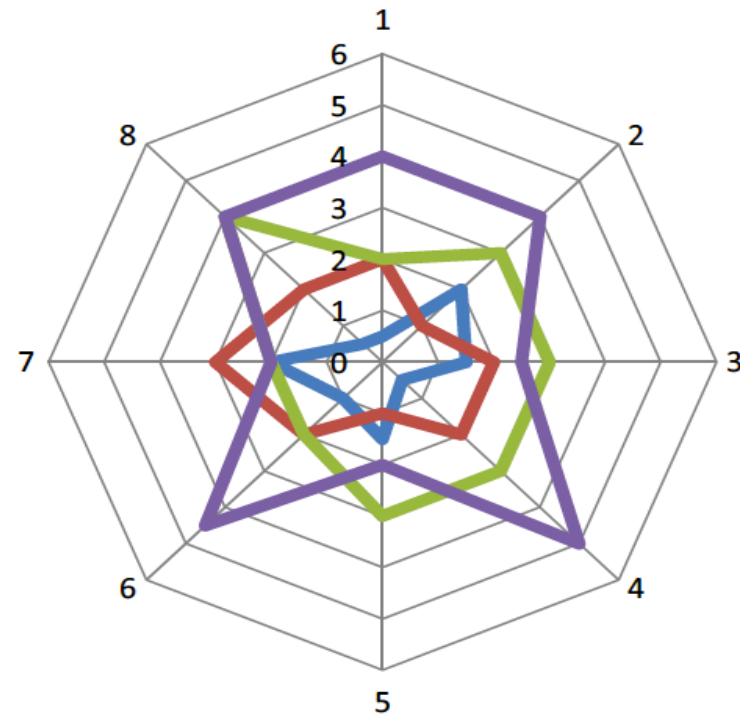
# Self = Consciousness?

## The minimal self



Blanke & Metzinger *Trends Cogn Sci* 2008

## States of Consciousness



Bayne, Hohwy, Owen. *Trends Cogn Sci* 2016



# Conclusions

- Consciousness in non-communicating states needs to be inferred: need of a framework for used technologies (Demertzi et al, *Neurosci Consciousness* 2017)
- Consciousness carries a moral significance
- Consciousness is not out there to capture

**Consciousness concerns us all**



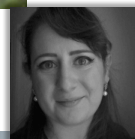
a.demertzi@uliege.be



## Coma Science Group & PICNIC Lab

The departments of Neurology and  
Radiology in Liège and Paris

**...and mostly patients and their  
families!**



James S. McDonnell Foundation



Human Brain Project



esa  
European Space Agency

Inserm  
Institut national  
de la santé et de la recherche médicale

Université  
de Liège



fnr's  
FREEDOM TO RESEARCH